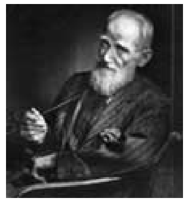
Ghoti



Ghoti papers

Ghoti aims to serve as a forum for stimulating and pertinent ideas. Ghoti publishes succinct commentary and opinion that addresses important areas in fish and fisheries science. Ghoti contributions will be innovative and have a perspective that may lead to fresh and productive insight of concepts, issues and research agendas. All Ghoti contributions will be selected by the editors and peer reviewed.

Etymology of Ghoti

George Bernard Shaw (1856–1950), polymath, playwright, Nobel prize winner, and the most prolific letter writer in history, was an advocate of English spelling reform. He was reportedly fond of pointing out its absurdities by proving that 'fish' could be spelt 'ghoti'. That is: 'gh' as in 'rough', 'o' as in 'women' and 'ti' as in palatial.

The barefoot ecologist goes fishing

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Abstract

Haliotid (abalone) fisheries are comprised of small-scale (<5 km^2) stocks and serve as a model for many such fisheries. Extremely valuable to local fishing communities in aggregate, these micro-stocks are myriad and complex to study, monitor, assess and manage. Micro-stocks need assessment and management at local scales to prevent small components from suffering the tragedy of commons. This paper asks how can we ever hope to address the research and management needs of so many small resources? Community-based and territorial rights-based systems may help in sustaining these resources, but servicing the technical needs of many small communities of stakeholders raises problems. A new generation of 'barefoot ecologists' is envisaged to perform this task.

Keywords barefoot ecologist, haliotids, micromanagement, micro-stocks, scientific fishing, TURF

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Introduction

It is now widely accepted that the dispersal of haliotid larvae, juveniles and adults is generally limited to tens to hundreds of metres (Prince *et al.* 1987, 1988b; McShane *et al.* 1988; Brown 1991; McShane 1992a, 1998; Tegner 1992; Shepherd and Brown 1993). Functional units of stock, in the sense of Gulland (1969), have scales of hundreds to thousands of metres, rather than the tens to hundreds of kilometres originally inferred. Regional fisheries consist of thousands to ten thousands of relatively independent self-recruiting units, or micro-stocks (Sluczanowski 1984, 1986; Hilborn and Walters 1987; Prince 1989; McShane 1998).[1]

If micro-stocks were biologically similar, and fishing pressure was distributed evenly so that fishing mortality was similar for each micro-stock, there would be little implication for assessment and management (Fukuda 1973; Garrod 1973). Component micro-stocks could be managed in aggregate and classic regional management should work.

Unfortunately, nature is not that simple. The growth of abalone is extremely plastic, adapting to a wide range of local conditions (Leighton and Boolootian 1963; Poore 1972; Day and Fleming 1992). Growth and the maximum size attained is highly variable between nearby individuals and populations (distances of 1–1000 m) and across the geographical range of each species (Poore 1972; Shepherd and Hearn 1983; Prince 1989; Day and Fleming 1992; McShane and Naylor 1995; Wells and Mulvay 1995; Worthington and Andrew 1998; Naylor and Andrew 2001). Maturity is principally determined by age rather than size (Shepherd and Laws 1974; Sainsbury 1982; Prince 1989; McShane 1991; Nash 1992). So, populations of the same species commence breeding at the same age over broad regions but over a wide range of sizes (Prince 1989; Nash 1992).

Contrary to much of the literature, young abalone have high rates of natural mortality and remain hidden in the interstitial spaces of reefs, where they are virtually invisible to fishers and researchers (Witherspoon 1975; Sainsbury 1982; McShane and Smith 1988; Prince *et al.* 1988c; Tegner 1989; McShane 1992a). At maturity, cryptic juveniles emerge from the interstitial spaces of the reef and join adult feeding and breeding aggregations on the exposed surface of the reef, where they are highly vulnerable to divers who learn and remember aggregation sites (Witherspoon 1975; Prince *et al.* 1988b; Prince 1989; Wells and Mulvay 1995).

Regional legal minimum lengths (LMLs) and catch controls have very different effects on component populations within a haliotid resource (Sluczanowski 1984, 1986; McShane 1992b). In productive fast-growing areas, abalone mature and emerge at larger sizes than in slower growing areas (McShane 1991; Prince *et al.* 1998). A 'stunted' or slow-growing population with a size of maturity well below the LML has a high proportion of breeding biomass protected from fishing, while the breeding biomass of a nearby fast-growing population that matures and emerges above the LML may be legally removed (Sluczanowski 1984, 1986, Hilborn and Walters 1987; McShane 1991; Prince *et al.* 1998).

Moreover, fishing pressure is never applied evenly, instead it focuses on a few reefs according to a sliding scale of preferences. Abundance of legal size abalone is the major priority for a diver, but the choice of dive site is honed by proximity to port, depth, and exposure to swell (Prince 1989). Adult abalone actively re-aggregate around the same points, which are quickly learnt by divers (Prince 1989, 1992). If unprotected by minimum size limits, focused fishing pressure results in localized depletions, recruitment collapses and eventually localized extinctions. Unfortunately, fishing pressure concentrates on areas with the highest size of maturity and where LMLs afford breeding stocks least protection, because by definition that is where legal sized abalone can be most easily collected (Prince 1989; Prince and Hilborn 1998; Prince *et al.* 1998). Component micro-stocks are prone to recruitment overfishing eventually leading to local extinctions, fishing pressure then refocuses on the next most preferable micro-stocks and the process continues leading to the sequential

[1]My doctoral work confronted me with the spatial complexity of haliotid populations. The consequent complexity of assessing and managing these resources fired my interest in working with commercial abalone divers, and, in turn, led me to become both commercial abalone diver and stock assessment scientist. Spanning both sides of this equation I can no longer claim to be scientifically dispassionate. I can only hope that the cited body of scientific work supports my claim to be scientifically passionate (Fig. 1). After working with a classic large-scale fishery, for Western Australian lobster (Phillips and Brown 1989), I found my conception of fisheries inappropriate when I began work on Tasmanian abalone (*Haliotis rubra*). Abalone larvae remain in the water column for 8–10 days with an apparant dispersal potential of 60–80 km (Tegner and Butler 1985). Size at maturity was assumed to be relatively uniform and the fishery was managed regionally (over hundreds of kilometres of coastline) with minimum size limits, limited entry and individually transferable quotas (Prince and Shepherd 1992). After learning some respect for the opinions of abalone divers in national spearfishing championships, I began my field studies by diving and talking with them. I found that they did not ascribe to many of the scientific dogmas. The divers described localized phenomena (hundreds to thousands of metres) which seemed incompatible with the assumption of broad scale units of stock; 'stunted stocks' where adults may never reach legal minimum length, and 'nonrecovery bottom' where local extinctions occurred after a few years fishing. As a consequence, I developed and applied new techniques for tagging, ageing and sampling juveniles (Prince and Ford 1985; Prince *et al.* 1988a; Prince 1991) and began testing alternate points of view (Prince *et al.* 1987, 1988b,c; Prince 1989).

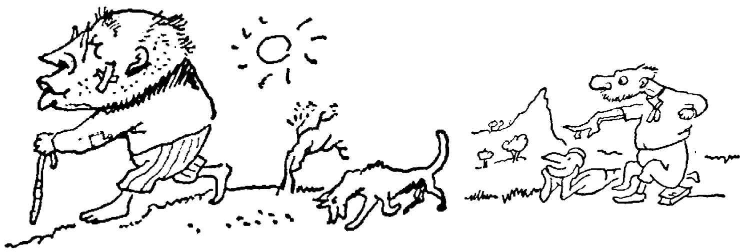

Figure 1 The first 'barefoot ecologist' may have been Fruitfoot, from an epic poem by Mervyn Peake (1972; of Gormeghast fame). 'Look! Look! Here cometh Fruitfoot: out of the wilderness, a fire in his belly, a purpose in his head; and a nose for the truth.

depletion of meta-populations (Sluczanowski 1984, 1986; Harrison 1986; Hilborn and Walters 1987).

Compounding matters, regional LMLs have often been set too low. With an eye to the logistics of dive-based research programmes and with little expectation of actual levels of variability, the first researchers tended to choose relatively sheltered research sites containing relatively 'stunted' stocks for the studies of growth and maturity.

Stunted stocks and nonrecovery bottom

Commercial divers in every abalone fishery refer to 'stunted' and 'shorty' abalone populations, or something similar, where abalone are found in high concentrations (Sluczanowski 1986; Sloan and Breen 1988; Nash 1992; Prince and Shepherd 1992; Wells and Mulvay 1995). These are self-recruiting populations that persist in the fishery because local conditions cause the abalone to mature and attain maximum sizes near or below the regional LML (McShane 1991; Nash 1992).

Older and retired abalone divers will speak of areas they call 'nonrecovery bottom' which failed to recover from fishing and represent the other extreme. Recently, Shepherd and Baker (1998), Shepherd and Rodda (2001) and Shepherd *et al.* (2001) have provided the scientific description of this phenomenon. Typically, these areas are characterized by a large size at emergence relative to the regional LML, and flat, relatively open reef habitat. Fishing pressure focused on these areas because the uniformly large size and flat topography ensured highly efficient searching and high-catch rates. This soon stripped away the original breeding stock leading to localized depletions. Recruitment failure may have been exacerbated by the flat topography, which restricts crevice habitat for settlement.

When initially fished, these 'nonrecovery' areas supported large catches at high-catch rates. These only lasted several years and sometimes only several dives, before the original biomass was exhausted. Five to 10 years of lower catches followed (although still at high-catch rates), until the pre-fishery recruitment had emerged, aggregated and been collected. Catches from these areas then collapsed. A short dive every couple of years is all that is needed to visit all the remembered aggregation points and clean up any remnant recruitment that may be beginning to rebuild a population.

Figure 2 is a map of Cape Leeuwin, Western Australia, prepared with the help of the first abalone divers in the area (Prince *et al.* 1998). The original size of the abalone is mapped, which is indicative of the original size of maturity. The regional LML had been set too small for this area; preserving high levels (70–90%) of the breeding biomass on the 'small' reefs, and moderate levels (<30%) in the 'small-to-average' sized areas. While the 'average', 'average-to-large' and 'large' growing reefs could be legally stripped, provided a diver had sufficient quota. However, as quota is allocated over a 700-km stretch of coastline it is almost never limiting at the scale of these micro-stocks. With some intuitive understanding of abalone, the local divers at first maintained a voluntary minimum length considerably above the legal LML. Their voluntary minimum size preserved around 50% of breeding stock on the 'average-to-large' reefs and limited the extent of 'nonrecovery bottom'. This agreement stabilized catches around 30 tonnes year^{-1} during the early 1980s. However when a single diver broke the voluntary agreement and began using the legislated LML, a short-lived competitive gold rush followed, substantially reducing the biomass and extent of breeding stocks. By the early 1990s, production had fallen to around 7 tonnes year^{-1} and was still declining, only 'small', and 'small-to-average' size of maturity areas were producing, the rest had been transformed into nonrecovery bottom.

The tyranny of scale

The plasticity in abalone size at maturity, together with the localized scale of larval dispersal, confounds the management and assessment of abalone fisheries (Sluczanowski 1986; Prince and Shepherd 1992; McShane 1998; Prince and Hilborn 1998). A tyranny of scale (Prince *et al.* 1998) results from management operating at scales of 100–1000 km, data collection and assessment on a scale of 1–10 km, while population dynamics within functional units of stock act on scales of 10–100 m. Prince and Hilborn (1998) emphasized the need to expand understanding of the resource and think of the resource as a complex spatial pattern.

The prompt application of regional size limits, limited entry, and ITQs in Australia and New Zealand effectively controlled development and stabilized the fishery (Harrison 1986; Prince and Shepherd 1992). But despite the superficial appearance of stability, the 'tragedy of the commons' (Hardin 1968) is still occurring at the scale of individual micro-stocks. With regional management fishing pressure focuses on micro-stocks with large sizes of maturity, closest to port, or in shallow and relatively protected water (Prince 1989; Prince and Hilborn 1998). Educated divers with large investments in the fishery knowingly apply LMLs that strip away remnant breeding stock, while rationalizing; 'If I don't do it, the next diver will' (Prince *et al.* 1998). Serial depletion and local extinctions continue below the scale of management, while pressure upon the remaining productive beds steadily escalates, all within the 'safe keeping' of regional catch limits and LMLs (TAFI 2000). This 'tyranny of scale' prevents otherwise effective management strategies addressing the 'tragedy of the commons'.

The tyranny of scale renders stock assessment unreliable (Harrison 1986; Hilborn and Walters 1987; Prince 1989; Breen 1992; Prince and Guzmán del Próo 1993; Prince and Hilborn 1998; TAFI 2000). Catch and effort data is aggregated over many (hundreds to thousands of) micro-stocks and within each micro-stock abalone actively reform aggregations around stable points in the reef (Prince 1989, 1992). Divers allocate searching time across a concentration profile of remembered aggregations, visually checking them before deciding to dive (Prince and Hilborn 1998). Consequently, at the scale of micro-stocks and aggregations catch rates tend to remain linearly related and catch rates remain hyper-stable until the final phase of a stock collapse (Prince 1989, 1992; Prince and Guzmán del Próo 1993). Rather than reflecting stock abundance aggregated CPUE trends reflect the choice divers make between dive sites (Prince 1989, 1992; Prince and Hilborn 1998). Higher catch rate areas have higher densities of abalone because factors deter frequent diving (i.e. deeper, exposed coast, far from port). By influencing the choice of dive site, material factors influencing incentive, such as beach price and management regimes, drive CPUE trends (Prince 1989; Prince and Hilborn 1998). Nevertheless, because funding limitations restrict the number of research surveys many stock assessment processes remain wedded to catch rate data aggregated over hundred to thousands of micro-stocks. Surveyed trends also tend to be regionally aggregated over many micro-stocks, rather than used as indices of the micro-stock surveyed, because the complementary catch data can only be collected on the larger scale, and, there are too few surveys to index a significant proportion of micro-stocks (e.g. government surveys in Victoria, Australia and New Zealand).

Coarsely aggregated stock assessments typically interpret trends in an abalone fishery as the slow decline of a large and unproductive original biomass (Prince and Guzmán del Próo 1993). The reality is a combination of the disparate trends from many smaller but productive populations, but there is rarely sufficient fine-scale data to show this. These biases cause actual levels of depletion to be under-estimated along with the true productivity of the original resource.

Re-introducing and re-building breeding aggregations restores productivity, but there are very few recorded incidences of this occurring. When the diver who broke the voluntary agreement in the Cape Leeuwin area (Fig. 2) left the fishery, voluntary size limits were restored, brood stock translocations occurred, and annual catch was rebuilt to over 30 tonnes by 2001. But such rehabilitation does not normally occur because the organizational capacity required to voluntarily implement a complex of reef-by-reef size limits, quotas, translocations and closures, is generally beyond competing divers, while the local knowledge and fine scale mechanisms are beyond centralized 'small' governments.

Too much environment and not enough taxpayers to pay for it all

The tyranny of scale is not confined to abalone fisheries, but is observed widely across the world's fisheries. Many benthic invertebrate and tropical reef

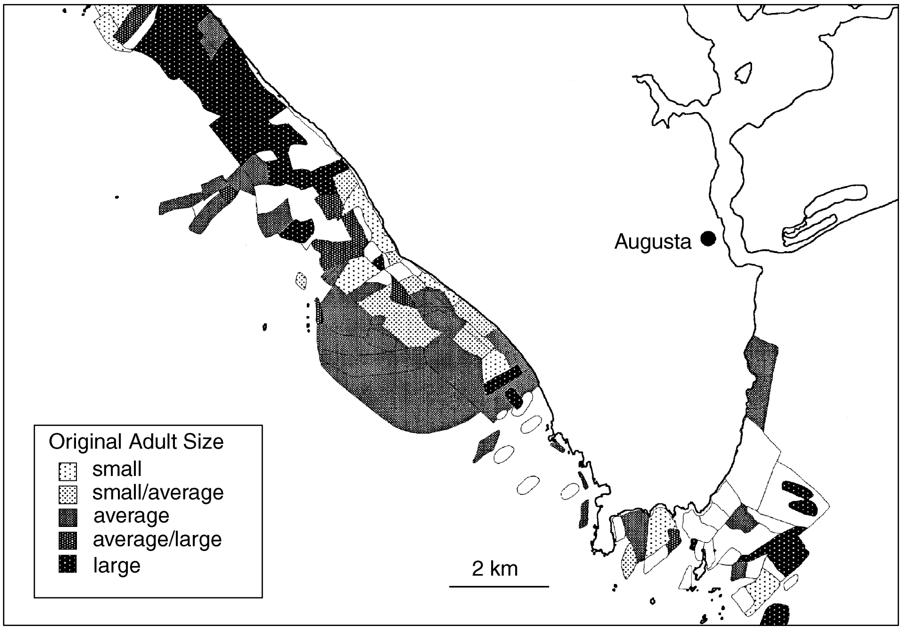

Figure 2 A map of the abalone beds around Cape Leeuwin, Western Australia, prepared in collaboration with the original divers to fish the area. The recollection of the divers, together with aerial photography, and ground-truthing dives have been used to qualitatively map the original 'unfished' size distribution of abalone as either small, small-to-average, average, average-to-large, or large. This is taken to be indicative of the variation in size of maturity across the area.

fisheries have the same intricate small-scale stock structure (Orensanz and Jamieson 1998). At larger scales many teleost and even shark fisheries with multiple breeding stocks are to varying degrees also subject to tyranny of scale effects; take for example the Norwegian (Maurstad and Sundet 1998) and Nova Scotian cod fishery (Gosse *et al.* 2003), the deep-water orange roughy (Bell *et al.* 1992), the Pacific North American salmon fisheries (Walters and Cahoon 1985) and even the soupfin shark fishery of Australia (Punt *et al.* 2000). Fed by an explosion of geo-positioning and genetic typing, understanding of spatial complexity is growing rapidly. But stock assessment and management thinking about stock structure tends to remain crude. For example, Patterson *et al.* (2001) in their review of Bayesian techniques for assessing uncertainty in stock assessment and forecasting, do not even list spatial complexity amongst the assumptions used to structurally condition models.

Dispersal and movement is not a simple phenomena (Fig. 3). Species and populations maintain a range of differing behaviours (i.e. McDowall 2001) and a few individuals move long distances in contrast to the majority. Over geological and evolutionary times, such minorities may be vital for colonizing new habitat as natural processes, like sea level changes, create and destroy habitat. We have tended to link the scale of functional stocks to these maximum distances moved by a species, the longest tagging movements, or the scale of genetic isolation. But for management purposes the shorter 'normal' distances moved within one or two seasons best indicate the scale of functional management units in a fishery.

From this perspective, it becomes clear that the world's fisheries contain a myriad of micro-stocks, raising a technical challenge in managing, monitoring and assessment. The difficulties and costs are proportional to the number of functional units, not their size or value. Likewise, the cost of the required research is not strongly linked to the value of resources, but more clearly related to the number of units involved. Larkin (1997) proposed a rule of thumb that the cost of research and management cannot sustainably exceed 10–20% of the value of the fishery. But when the cost of a single researcher with government overheads approaches Aus$100 000 per annum; what does one do with a fishery full of micro-stocks each worth less than this? Micro-stocks are valuable to local communities in aggregate, but myriad and complex to assess and manage. How could we ever hope to address the needs of so many micro-stocks? Academics in universities and governmental agencies are too few to assess and manage

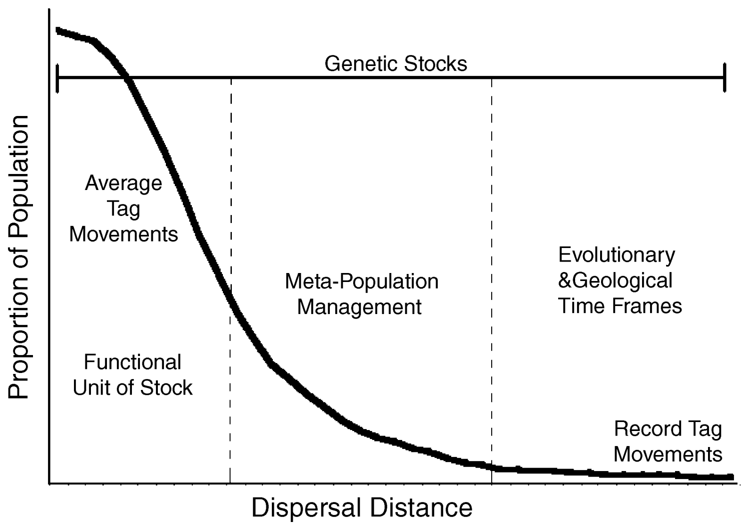

Figure 3 An indicative curve illustrating the proportion of a biological population and the distance they move, or disperse. The curve is meant to illustrate that dispersal is not a simple phenomena and should be conceptualized as a distribution curve rather than a simple mean distance or rate. Such functions are maintained by evolutionary processes. Long distance dispersal by relatively few individuals determines the size of genetic populations, maintains genetic diversity and a species invasive ability maintaining its distribution over geological time frames. Much smaller feeding and breeding movements by the majority of individuals determine the scale of functional units of stock for assessment and management purposes.

all these micro-marine resources. Meanwhile, the role of central government is shrinking, not expanding, as taxpayers demand leaner and smaller governments. There is simply too much environment, and not enough taxpayers to pay for it all.

In the developed countries, fisheries management remains the last great bastion of the Command-Control Theory of government. Management, monitoring and assessment processes are reserved for centralized governments. The assumption is that fishers cannot be trusted, and must be compelled by legislation to fish sustainably. But when it comes to micro-stocks the emperor has no clothes because centralized governments are incapable of allocating the decentralized resources required for the task.

Tasmania, Australia, which has the largest remaining abalone fishery, will serve as an example. Despite its complexity, I argue that the fishery has the financial and social capital required to manage itself. For example, George III Rock, a 360 000 m^2 reef, produced an annual recruitment of approximately 5000 abalone into an adult population of 25 000 abalone (Prince 1989). Recruitment had probably been higher from a previously larger parental biomass, and could be sustained harvesting 4000 abalone/year worth around Aus$150–200 000. After modest installation costs, an accurate micro-stock scale stock assessment based on fishery independent surveying would cost about Aus$15 000 per year, well within Larkin's rule-of-thumb for affordable assessment and management. Hence, if extended to the entire Tasmanian resource, the approximately 1000 micro-stocks in the Tasmanian fishery would cost about Aus$15 million. In fact, only a reasonable proportion of micro-stocks would need to be covered to place the stock assessment on a secure footing.

In contrast, in 2000 Tasmania's 125 commercial divers and quota holders paid approximately Aus$16 million in license fees, for a Total Allowable Commercial Catch worth about Aus$100 million (beach price). Meanwhile, total expenditure on the management, research and assessment of this fishery was only around Aus$2 million, most of that was spent on the Quota Management System (Mr W. Ford, Tasmanian Department Primary Industry and Fisheries, Hobart, personal communication). The small research programme is basically left to a single researcher and a few technical officers, with a 4WD vehicle and a dinghy. In my view, none of the micro-stocks is reliably assessed or managed.

The state agencies who manage abalone in Australia have recently agreed that the development of micromanagement is a priority. Nevertheless, in the western zone of Victoria, Australia, requests for government assistance to help enforce voluntary agreements on sizes and catches made by the Western Abalone Divers Association were declined because enforcement could not be adapted to the fine scale requested by the divers.

Beyond centralized management – abalone gardens

With apologies to Aldo Leopold: 'relegating conservation to government is like relegating virtue to the Sabbath. It turns over to [so very] few professionals what should be the daily work [of a vast army] of amateurs' (Meine and Knight 1999). The tragedy of the commons socially constrains people so that they act against the long-term communal good for short-term personal profit. Hardin (1968) argued that the 'tragedy of the commons' does not have a technical solution, rather it is a social issue requiring society to change and develop new patterns of behaviour.

Sustaining and optimizing haliotid production requires maintaining productive breeding stocks on all abalone reefs. This requires reef-by-reef size and catch limits at scales that can only be assessed and implemented by informed and motivated divers. I believe divers may be enabled to change from being marine hunters, competing amongst themselves and 'bringing ruin to all'. They could be empowered to become marine gardeners, co-operatively tending and harvesting 'abalone gardens'. We need them to be resource surveyors, assessors, managers and harvesters. I term this 'scientific fishing'. Fishers are the key to micromanagement because, as members of the local community, they already have effective custody of the resources, even when this is not formally recognized with property rights. Failure to appreciate this will continue the de-humanizing processes that currently contribute to depletion.

With species subject to the tyranny of scale, some form of Territorial User Rights Fishery (TURF) or Customary Marine Tenure (CMT) can provide the motivation and the control needed for local communities and individuals to manage localized marine resources (Orensanz and Jamieson 1998). Recent experiences in Chile (Castilla *et al.* 1998) and Vanuatu (Johannes 1998a) demonstrate the creative 'learning by doing' approach to management (Walters and Holling 1990) that local communities and individuals adopt when given control over local resources.

Agents of change: barefoot ecologists

But, who will service the technical needs of all those local stakeholder communities managing all those micro-stocks? Certainly not the expensively trained experts from governmental agencies and universities. In the 1950s, China realized that medical skills were required in every village throughout that massive country, but there was a critical shortage of trained doctors. China responded effectively with 'barefoot doctors', who were low-cost, generalists recruited from local communities and given simple basic training to deal with core village ailments.

The answer put forward in this paper is to create the equivalent of the 'barefoot doctors' of China, 'barefoot ecologists' (Fig. 4b).[2] Barefoot ecologists will need to be pragmatic generalists, skilled in the multiple disciplines required to work effectively with micro-stocks and in diverse fishing communities. They could be termed holistic ethno-socio-quantitative fisheries ecologists. In local communities, the barefoot ecologist will catalyse change and build social capital within fishing communities. Their role will be to motivate and empower fishers to research, monitor and manage their own localized natural resources. While working to strengthen existing endogenous community structures, the barefoot ecologist can support the development of social structures that foster community-based management and data collection.

For each new community and micro-stock, the starting point for a 'barefoot ecologist' will be the application of data less management (Johannes 1998b), gleaning local knowledge, reading the comparative literature, offering basic biological information to fishers and recommending sensible 'rule-of-thumb' management. In this first stage, barefoot ecologists will require expertise in survey design, because their aim will be to implement long-term community-based population abundance and environmental monitoring systems.

The aim of the 'barefoot ecologist' will be to identify strategic opportunities to gather scientific data. When communities of fishers perceive their own over-capacity for fishing, and realize their need for both income and data, they become increasingly prepared to fish to prearranged fishery independent patterns and record data. By combining elegant survey design and community involvement, much fishery-independent data can be collected by fishers engaging in 'scientific fishing', with only a marginal sacrifice in fishing efficiency.

[2]The 'barefoot ecologist' idea derives from long debates in the early 1990s with the late Dr Philip Slucanowski.

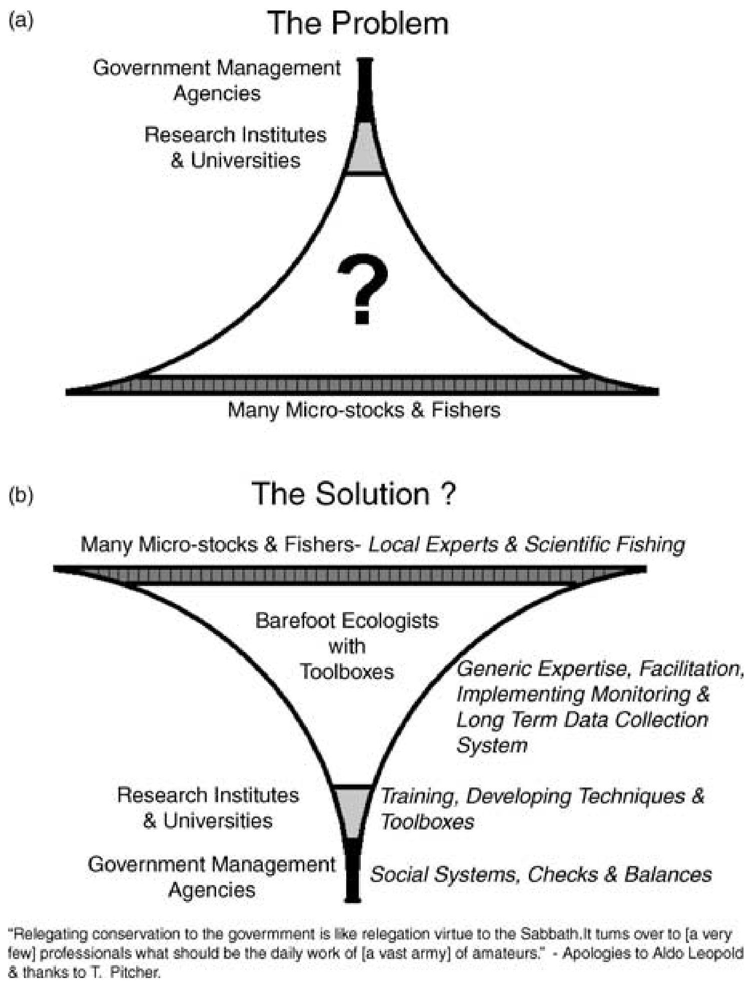

Figure 4 (a) The problem. An illustration of the current lack of practitioners in the field of sustainable fisheries. From the perspective of this paper, a major problem for the field is the great gap between the global needs of the large number of micro-stocks and fishing communities and the limited resources of the government funded fisheries agencies, research institutes and universities. (b) The solution? As proposed by this paper, the technical needs for assessing and managing micro-stocks, and the fishers who depend upon them, could be answered by a new class of fisheries ecologists called 'barefoot ecologists'. Following the example of the Chinese 'barefoot doctor' programme this paper proposes basic but holistic training for 'barefoot ecologists' with the aim of facilitating and empowering management by fishing communities.

Having strengthened community-based data gathering, and started a discussion of management and assessment frameworks, the active role of the 'barefoot ecologist' may become reduced. The job then turns to accumulating time-series data and improving the reliability of stock assessment and the sophistication of management. For this long-term phase, the 'barefoot ecologist' needs to be versed in quantitative management processes like 'adaptive environmental assessment and management' (Walters 1986), and 'back to the future' (Pitcher *et al.* 1998), which can capture diverse information streams and simulate alternative scenarios for community discussion and decision making. A consequent advantage is that 'barefoot ecologists' will be seen to serve the communities with which they work, rather than a central government agency. This type of participant/adviser role is well-developed and accepted in the agricultural sector, but almost nonexistent and even frowned upon, in fisheries.

This suggestion is not meant to imply a reduced role for government agencies or academic institutions but is a call for clearer thinking about differing but complementary roles (Fig. 4b). Government agencies need to develop legislation that supports the evolution of social systems, like TURF and CMT, which encourage sustainable fine-scale behaviour. Government also needs to legislate to protect broader standards approved by the community (e.g. biodiversity and natural heritage), provide for checks and balances, and establish auditing procedures. Specialized expertise will be needed to train and equip 'barefoot ecologists'. Research agencies and universities may have a continuing role in discovering and publishing scientific knowledge, and developing innovative techniques and tools for the 'barefoot ecologists' to use.

The barefoot ecologists toolbox: a millennium project

'Barefoot ecologists' will need to be armed with toolboxes. Like the famous Hitch-Hiker's Guide to the Galaxy (Adams 1979), the Barefoot Ecologist's Toolbox might be a hand-held computer programmed to be useful in every situation.[3] It might contain the handbooks of a diverse training, allow access to the scientific literature from remote locations, and contain a standardized, general-purpose software that can do almost anything if required, even if most only ever use it for the basics.[4]

The germ of the 'barefoot ecologist' idea is to facilitate the *in situ* collection of appropriately scaled fisheries data through the development of a user friendly generic software toolbox for use by fishers (Sluczanowski 1993). With the help of a 'barefoot ecologist' to establish survey systems and initialize software, fishers armed with a lap-top could be equipped to monitor and manage many of their local micro-stocks. Over time, the software adaptation for each micro-stock would become proof of the value of that resource and create a cycle for improving data quality and allow fishers to control access to their own data. By transferring responsibility, motivation and ownership of the data to fishers, the aim is to side-step the problem of data confidentiality which commonly undermines government agency attempts to collect accurate spatially explicit data.

One imagines that in time there will be many marine gardeners, advised by 'barefoot ecologists', applying their own individual expertise and intuition to optimizing local fisheries. As suggested by Walters and Holling (1990), much will be learnt by conducting comparative analyses of these diverse approaches to resource management.

Un-orchestrated competition amongst researchers for funding, publication and kudos may make for a lively field of scientific endeavour as researchers squirrel away the knowledge of fishers to advance their own careers. I think it is time our field matured and began to integrate its skills and intellectual property, so that they can be applied efficiently to the obvious needs that confront us. Collectively, fisheries scientists already possess the thinking, course material, field techniques, models and software code needed to begin training and equipping a legion of 'barefoot ecologists'. Working together, each contributing a small part, the global community of fisheries ecologists and modelers could look forward to fully equipped 'barefoot ecologists' taking up their practices before the end of the first decade of this new millennium.

[3] As long as the user does not panic!

[4] Anyone watching Carl Walters (UBC) work will have seen him using his own personal toolbox. Generic software, he has developed over decades, which he rapidly adapts to analyse and interpret the dynamics of every resource; from the water balance of the Florida Everglades to the sustainable yield of western rock lobster. The basic ingredients include: mapping software for mapping stocks and survey designs; spreadsheet for capturing and storing long-term data sets (catch, effort and surveys); data analysis and assessment models. But the real power of the Walters' toolbox is visualization, both for visual analysis of historic trends, and also for real-time scenario gaming of alternative futures (Walters 1986). It was the potential for unlocking insight and community involvement through visualization that really excited Slucanowski when he met Walters during the 1980s (Prince *et al.* 1991; Sluczanowski *et al.* 1992) and that provided our motivation for designing a barefoot ecologists' toolbox.

Acknowledgements

At the August 2001 Conference at UBC on Putting Fisher's Knowledge to Work, it was heartening to see so many First Nation peoples, commercial fishers and researchers. This paper presents my personal perspective on the imperative for pushing beyond simply making more efficient use of fisher's knowledge. I owe a great debt to the late Bob Johannes' seminal 'Words of the Lagoon' (Johannes 1978). I thank Tony Pitcher for bringing the Aldo Leopold quote to my attention.

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